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(54) COMPOSANT STRUCTURAL CONSTITUE D'UN ALLIAGE D'ALUMINIUM DU TYPE ALMGSI
(54) STRUCTURAL COMPONENT MADE OF AN ALUMINUM ALLOY OF THE A1MGSI TYPE

(57)
An alloy of the AlMgSi type which is suited for producing structural components which are highly capable of absorbing kinetic energy by means of plastic deformation contains silicon provided in a wt. % ranging from 0.45 to 0.85, magnesium in a wt. % ranging from 0.35 to 1.0, copper in a wt. % ranging from 0.05 to 0.30, iron in a wt. % ranging from 0.05 to 0.25, vanadium in a maximum wt. % of 0.25, manganese in a maximum wt. % of 0.10, as well as impurities which result during production in a maximum wt. % of 0.05 individually and 0.15 in total, and aluminum as the remainder wt. %. The structural component is manufactured from a rolled strip or sheet of the alloy. Components made of this alloy are suited as safety parts used in the construction of vehicles. The alloy is also suited for producing vehicle body parts which comprise a high degree of flexibility without the occurrence of cracking and orange peel effects, in particular, for producing two-sheet structures such as an engine hood, door, and trunk lid of a passenger car. These structural components and vehicle body parts can be easily recycled together.

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(54) Titre : COMPOSANT STRUCTURAL CONSTITUE D'UN ALLIAGE D'ALUMINIUM DU TYPE AlMgSi
(54) Title: STRUCTURAL COMPONENT MADE OF AN ALUMINUM ALLOY OF THE AlMgSi TYPE

(57) Abrégé/Abstract:
An alloy of the AlMgSi type which is suited for producing structural components which are highly capable of absorbing kinetic energy by means of plastic deformation contains silicon provided in a wt. % ranging from 0.45 to 0.85, magnesium in a wt. % ranging from 0.35 to 1.0, copper in a wt. % ranging from 0.05 to 0.30, iron in a wt. % ranging from 0.05 to 0.25, vanadium in a maximum wt. % of 0.25, manganese in a maximum wt. % of 0.10, as well as impurities which result during production in a maximum wt. % of 0.05 individually and 0.15 in total, and aluminum as the remainder wt. %. The structural component is manufactured from a rolled strip or sheet of the alloy. Components made of this alloy are suited as safety parts used in the construction of vehicles. The alloy is also suited for producing vehicle body parts which comprise a high degree of flexibility without the occurrence of cracking and orange peel effects, in particular, for producing two-sheet structures such as an engine hood, door, and trunk lid of a passenger car. These structural components and vehicle body parts can be easily recycled together.

Abstract

An AlMgSi type of aluminium alloy suitable for manufacture of structural parts with a high capacity for absorbing kinetic energy by plastic deformation contains 0.45 to 0.85 wt.% silicon, 0.35 to 1.0 wt.% magnesium, 0.05 to 0.30 wt.% copper, 0.05 to 0.25 wt.% iron, at maximum 0.25 wt.% vanadium, at maximum 0.10 wt.% manganese and individually at maximum 0.05 wt.% of impurities associated with alloy production, in total at maximum 0.15 wt.%, the remainder aluminium. The structural part is produced from the said alloy in the form of rolled strip or sheet. Structural parts made from the alloy are suitable as safety parts in automobile manufacture. The alloy is also suitable for manufacture of vehicle body parts with high bending capacity without forming cracks or exhibiting the orange peel effect, in particular for the manufacture of two sheet structures such as the bonnet, door and boot lid of a private car. Structural parts and body parts can be readily and simply recycled together.

Structural Part made from an AlMgSi Type of Aluminium Alloy

The present invention relates to an AlMgSi type of aluminium alloy suitable for manufacture of structural parts with a high capacity for absorbing kinetic energy by plastic deformation. The invention includes also a vehicle bodywork part with high capacity for bending without forming cracks or exhibiting the orange peel effect, in particular in the form of a two sheet structure such as the bonnet, door and boot lid for a private car.

Crash behaviour is an increasingly important aspect of vehicle manufacture; this applies both to road bound and rail bound vehicles. The manufacturers of road and railway vehicles are increasingly favouring dimensioning special components and even complete construction units of the vehicle in such a way that on collision as much energy as possible is absorbed in order to reduce the risk of injury to the passengers. Apart from the design of these so called crash elements, the mechanical properties of the materials and joints are of decisive import-ance. The aim is to achieve the maximum absorption of energy before fracture occurs. This can be achieved by means of a low ratio of yield strength to fracture strength. An important material characteristic is also a high elongation. Attention must also be given to the require-ments made of the finished part. From the construction standpoint e.g. a particular strength level, particular minimum values with respect to elongation, corrosion resistance or another essential characteristic may be specified.

The growing importance of producing lighter automobiles with a view to saving energy has led to the development of a large number of aluminium alloys for automotive applications. Ideally there should be only one single alloy which could be used for the various parts in the automobile. Especially with a view to processing scrap or recycling so called space frame structures in the automobile it would be desirable to be able to manufacture the frame parts, which are made today out of extruded sections, the car body sheet and structural components out of the same alloy. Different components in an automobile, however, frequently require different properties. For example, an aluminium alloy for outer body sheet applications should be highly formable in order to permit stretch drawing, deep drawing and bending, at the same time, however, exhibiting high strength after stove lacquering. In particular sheets for manufacturing two sheet structures such as bonnets, doors and boot lids should exhibit a high capacity for bending without forming cracks or exhibiting the orange peel effect, as these components are often joined by flanging.

Patent EP-A-0805219 discloses a structural part made from an AlMgSi alloy for use in vehicle manufacture. The structural part is made in a conventional manner by extrusion.

The object of the present invention is to provide a structural part of the kind described at the start which meets the crash behaviour requirements achieved by extruded structural parts. In addition it should also be possible for the alloy employed for the structural part to be employ-ed for manufacturing bodywork parts.

That objective is achieved by way of the invention in that the alloy contains

silicon	0.45 to 0.85 wt.%
magnesium	0.35 to 1.0 wt.%
copper	0.05 to 0.30 wt.%
iron	0.05 to 0.25 wt.%
vanadium	at maximum 0.25 wt.%
manganese	at maximum 0.10 wt.%

and individually at maximum 0.05 wt.% of impurities associated with alloy production, in total at maximum 0.15 wt.%, the remainder aluminium and the structural part is made of rolled strip or sheet of the alloy.

The following composition ranges are preferred for the alloy elements mentioned:

silicon	0.50 to 0.8 wt.%
magnesium	0.40 to 0.65 wt.%
copper	0.05 to 0.20 wt.%
iron	0.05 to 0.20 wt.%
vanadium	at maximum 0.20 wt.%.

The structural part according to the invention exhibits preferably a part shaped from sheet and joined to a tube-shaped part or hollow body. The tube-shaped part is preferably rect-angular in cross-section, may however in principle be of any desired cross-sectional shape. For more complex component geometries the tube-shaped part may be shaped further by applying hydroforming..

The connection of the sheet to a tube-shaped part may be effected by any desired method of joining e.g. by welding, adhesive bonding, riveting or screwing.

The alloy employed for the structural part may also be employed for manufacturing car body parts, in particular such in the form of two sheet structures such as bonnets, doors and boot lids of private cars, which considerably simplifies the processing of scrap or recycling of structural parts and car body sheets.

The structural part according to the invention is particularly suitable as a safety part in vehicle manufacture, especially in the automotive field.

The alloy according to the invention may be processed in the normal manner by extrusion, strip casting, hot and/or cold rolling to sheet or strip. In order to achieve the optimum properties with respect to crash behaviour and bending behaviour it has been found to be particularly favourable if a solution treatment is carried out in a continuous strip treatment furnace in a temperature range of 520 °C to 580 °C followed by quenching. The quenching may be performed in the normal manner – depending on sheet thickness – usually with water or air. In the case of solution treatment care must be taken to ensure that all the soluble constituents such as Si and Mg_2Si go into solid solution and are in a supersaturated state on cooling. The cooling rate can have a considerable effect on the mechanical properties as, if the cooling rate is too slow, the Si and Mg_2Si precipitate out on the grain boundaries and significantly impair the crash and bending behaviour. In addition, the capacity to age-harden and the corrosion behaviour are impaired.

The structural parts and bodywork parts are preferably employed in the artificially age-hardened condition, in particular in the heat treated condition T6. In the case of bodywork parts this heat treated condition can be created during the stove lacquering cycle.

The strips or sheets employed for the manufacture of the structural parts and bodywork parts according to the invention are preferably in a thickness range of 0.8 to 4 mm.

Further, the strips and sheets may be chemically or electrochemically pre-treated and/or coated with a dry lubricating agent before the final processing.

Further advantages, features and details of the alloy sheets according to the invention employed for manufacturing structural parts and bodywork parts are revealed in the following description of preferred exemplified embodiments.

Example No. 1

An alloy of the following composition

0.82 wt.% Si
0.57 wt.% Mg
0.22 wt% Fe

0.07 wt.% Cu
0.005 wt.% V
0.08 wt.% Mn

and, for comparison purposes, a standard alloy AA 6016 used for automotive applications were processed in a normal manner by continuous casting, hot and cold rolling to 1.2 mm thick sheet. The solution treatment was performed at 540 °C followed by quenching in water.

The mechanical properties and formability values measured on sheet samples of the alloy according to the invention and on the alloy for comparison, both in the T4 heat treatment condition, are compared in table 1.

Table 1

	R_m MPa	$R_{p0.2}$ MPa	A_{10} %	$n_{5\%}$	r	$f=r_i/t$
Invention	261	146	26.8	0.29	0.61	<0.1
AA 6016	254	138	28.5	0.29	0.59	0.3

The results in table 1 clearly show the better bending behaviour of the alloy according to the invention over that of the alloy AA 6016.

Example No. 2

An alloy of the following composition

0.59 wt.% Si
0.55 wt.% Mg
0.15 wt% Fe
0.07 wt.% Cu
0.10 wt.% V
0.08 wt.% Mn

and, for comparison purposes, a standard alloy AA 6016 used for automotive applications were processed in a normal manner by continuous casting, hot and cold rolling to 1.5 mm

thick sheet. The solution treatment was performed at 540 °C followed by quenching in water.

Table 2

	Con-dition	R_m MPa	$R_{p0.2}$ MPa	A_{10} %	$n_{5\%}$	r	$f=r_i/t$	Crash behaviour
Invention	T4	222	113	25.8	0.30	0.57	<0.1	3
Invention	T6	263	229	11.5	-	-	0.25	3
AA 6016	T4	254	138	28.5	0.29	0.59	0.30	3
AA 6016	T6	295	258	14.2	-	-	0.60	1

The results in table 2 clearly show the better crash behaviour of the alloy according to the invention over that of the alloy AA 6016, especially in the artificially age-hardened condition.

Example No. 3

An alloy of the following composition

0.60 wt.% Si
0.53 wt.% Mg
0.20 wt% Fe
0.14 wt.% Cu
0.15 wt.% V
0.07 wt.% Mn

and, for comparison purposes, a standard alloy AA 6016 used for automotive applications were processed in a normal manner by continuous casting, hot and cold rolling to 1.5 mm thick sheet. The solution treatment was performed at 560 °C followed by quenching in water.

Table 3

	Condition	R_m MPa	$R_{p0.2}$ MPa	A_{10} %	$n_{5\%}$	r	$f=r_i/t$	Crash behaviour
Invention	T4	212	112	26.4	0.28	0.52	0.15	3
Invention	T6	243	199	13.8	-	-	0.25	3
AA 6016	T4	232	124	27.6	0.29	0.61	0.40	2
AA 6016	T6	283	211	17.9	-	-	0.65	1

The results in table 3 clearly show the better crash behaviour of the alloy according to the invention over that of the alloy AA 6016, especially in the artificially age-hardened condition.

Example No. 4

An alloy of the following composition

0.57 wt.% Si
0.53 wt.% Mg
0.18 wt% Fe
0.07 wt.% Cu
0.006 wt.% V
0.07 wt.% Mn

and, for comparison purposes, a standard alloy AA 6016 used for automotive applications were processed in a normal manner by continuous casting, hot and cold rolling to 2.0 mm thick sheet. The solution treatment was performed at 560 °C followed by quenching in water.

Table 4

	Condition	R_m MPa	$R_{p0.2}$ MPa	A_{10} %	$n_{5\%}$	r	$f=r_i/t$	Crash behaviour
Invention	T4	191	120	24.4	0.22	0.50	0.10	3
Invention	T6	257	226	11.5	-	-	0.30	3
AA 6016	T4	215	131	24.8	0.24	0.58	0.40	2
AA 6016	T6	297	223	12.8	-	-	0.70	1

The results in table 4 clearly show the better crash behaviour of the alloy according to the invention over that of the alloy AA 6016, especially in the artificially age-hardened condition.

In the above examples 1 to 4

T4 = heat treatment condition: solution treated, quenched

T6 = heat treatment condition: solution treated, quenched, artificially age-hardened at 210°C for 30min (the T6 condition can also be achieved during a lacquer stoving cycle)

R_m = Tensile strength

$R_{0.2}$ = Yield strength

A_{10} = elongation

$n_{5\%}$ = work hardening coefficient n at 5% elongation

r = r-value (average perpendicular anisotropy)

f = r_i/t = bending factor (r_i minimum radius, t sheet thickness)

The crash behaviour was evaluated in a semi-static compression test with values of 1 to 3, where 3 is the best value. The semi-static compression test serves to assess energy absorbing components. The desired behaviour is characterised by way of uniform folding without forming cracks. The appearance of the compressed sample was evaluated with the value 3 (no cracks formed, uniform folding), 2 (roughened, slightly cracked) and 1 (cracks formed).

Amended claims of 13.12.2000

Amended Claims of 13.12.2000

1. Use of an aluminium alloy of the AlSiMg type having as composition (in wt.%)

silicon	0.45	to	0.85
magnesium	0.35	to	1.0
copper	0.05	to	0.30
iron	0.05	to	0.25
vanadium	at max.		0.25
manganese	at max.		0.10

   and individually at maximum 0.05 wt.% of impurities associated with production, in total at maximum 0.15 wt.%, the remainder aluminium, for a structural component made from rolled sheet or strip, shaped and joined to give a pipe-shaped part or hollow body with a high capacity for absorbing kinetic energy by plastic deformation as a safety component in vehicle manufacture.

2. Use according to claim 1, characterised in that the alloy contains 0.50 to 0.80 silicon.

3. Use according to claim 1 or 2, characterised in that the alloy contains 0.40 to 0.65 magnesium.

4. Use according to one of the claims 1 to 3, characterised in that the alloy contains 0.05 to 0.20 copper.

5. Use according to one of the claims 1 to 4, characterised in that the alloy contains 0.05 to 0.20 iron.

6. Use according to one of the claims 1 to 5, characterised in that the alloy contains at most 0.20 vanadium.

7. Use according to one of the claims 1 to 6, characterised in that the part is formed further by high internal pressure forming.

8. Use according to one of the claims 1 to 7, characterised in that the strip or sheet is made by continuous ingot or strip casting, hot and/or cold rolling and solution treatment in a continuous heat-treatment furnace in a temperature range of 520 to 580°C followed by quenching.

9. Use according to one of the claims 1 to 8 in the artificially age-hardened condition, in particular in the artificially age-hardened condition T6.